APPLICATION OF WATER-JET HORIZONTAL DRILLING TECHNOLOGY TO DRILL AND ACIDIZE HORIZONTAL DRAIN HOLES, TEDBIT (SAN ANDRES) FIELD, GAINES COUNTY, TEXAS

FINAL REPORT

PROJECT
DE-FG26-99BC15244

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For

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DISCLAIMER

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ABSTRACT

The San Andres Formation is one of the major hydrocarbon-producing units in the Permian Basin, with multiple reservoirs contained within the dolomitized subtidal portions of upward shoaling carbonate shelf cycles. The test well is located in Tedbit (San Andres) Field in northeastern Gaines County, Texas, in an area of scattered San Andres production associated with local structural highs. Selected on the basis of geological and historical data, the Oil & Gas Properties Wood No. 1 well is considered to be typical of a large number of San Andres stripper wells in the Permian Basin. Thus, successful completion of horizontal drain holes in this well would demonstrate a widely applicable enhanced recovery technology.

Water-jet horizontal drilling is an emerging technology with the potential to provide significant economic benefits in marginal wells. Forecast benefits include lower recompletion costs and improved hydrocarbon recoveries. The technology utilizes water under high pressure, conveyed through small-diameter coiled tubing, to jet horizontal drain holes into producing formations.

Testing of this technology was conducted with inconclusive results. Paraffin sludge and mechanical problems were encountered in the wellbore, initially preventing the water-jet tool from reaching the kick-off point. After correcting these problems and attempting to cut a casing window with the water-jet milling assembly, lateral jetting was attempted without success.

PURPOSE

The purpose of the project was to field-test emerging water-jet horizontal drilling technology in a typical Permian Basin San Andres stripper well. If the technique proved to be successful, multiple (4-5) small diameter horizontal drain holes, extending as much as 300 feet from the vertical well bore, were planned. Production rates were expected to increase as a result of: (1) increasing the total reservoir surface area exposed, (2) increasing the probability of intersecting natural fractures, (3) increasing the probability of opening additional reservoir compartments, and (4) increasing the effective reach of future stimulation treatments. Success of this project would demonstrate a viable new technology, widely applicable to enhancing the economics and total hydrocarbon recovery of marginal wells.

WATER-JET DRILLING TECHNOLOGY

Concept

Water-jet drilling is basically a jetting technique, utilizing a relatively incompressible fluid (water), under high pressures to disaggregate and penetrate rock. No bit is used; all cutting is done by water. Large hydraulic forces are generated in the small volume of rock immediately in front of the drilling nozzle, resulting in rapid microfracturing and wedging apart of rock particles at the point of jet impact. Dislodged rock particles are then removed by the backward flow of spent drilling fluid away from the drilling nozzle. Forward pressure on the drilling nozzle, and additional rock particle removal, is provided by backward directed water jets. It should be noted that the contractor has stated that both the drilling water and the production tubing must be clean for this technology to function properly.

Equipment

Advanced Petroleum Enhancement, Inc. supplied the equipment used in this project. The test was conducted under the supervision of Mr. Carl Landers, the inventor and key patent holder. As currently configured, the water-jet drilling equipment is trailer-mounted and self-contained. Primary components of the system include of a water tank, high-pressure pump, and small-diameter (3/8") stainless steel coiled tubing. A length of flexible high-pressure composite tubing is attached to the coiled tubing and is equipped with an interchangeable drilling nozzle. The drilling nozzle is configured with three very small diameter, angled holes on the drilling face and several backward directed holes at the rear of the nozzle. In operation, the nozzle slides but does not rotate. A specially designed production tubing sub-assembly, or elbow, containing a short-radius right angle channel is also provided. A milling assembly, consisting of a water-driven downhole motor, guides, and carbide mill bit, can be substituted for the jet nozzle when required for milling through casing. Pump pressure at the surface is approximately 5000 pounds per square inch; at a depth of 5000 feet jet pressure is approximately 4200 pounds per square inch. Auxiliary equipment includes water heaters, water filters, and electrical generators.

Operational procedures

All positioning of the elbow sub-assembly is accomplished by manipulation of the production tubing string. Orientation of the elbow, and thus the lateral drain hole, requires turning the production string. Specific orientation of laterals requires running a gyro survey. Depth changes are made by raising or lowering the production string. No down hole steering capability is presently available for this system, although the contractor has stated that the lateral boreholes tend to continue along the orientation of the elbow. In operation, the following procedure is followed:

1. Production tubing, with the elbow sub-assembly attached, is run into the hole to the required depth.
2. The coiled tubing(with attached high-pressure composite tubing and jet nozzle) is run into the production tubing and through the elbow.
3. Jetting is attempted to check for elbow alignment with existing perforations. If jetting is possible, alignment with a perforation is demonstrated and jetting continues. If jetting does not advance, the jet nozzle is pulled out of the production string to pick up the milling assembly. The production string and elbow remain in place.
4. The coiled tubing, with the milling assembly attached, is run back into the production tubing and elbow.
5. Casing is milled until a window is cut.
6. After cutting a window in the casing, the milling assembly is pulled out of the production string to again pick up the drilling nozzle.
7. The coiled tubing, with drilling nozzle attached, is run back into the production string and jetting proceeds.
8. This procedure is followed for each lateral hole attempted.

GEOLOGIC SETTING

San Andres Formation

The Oil & Gas Properties Wood # 1 well is located in Tedbit (San Andres) Field in northeastern Gaines County, Texas, an area of scattered San Andres production associated with local structural highs. These structures are the result of sediment drape over deeper fault blocks and are detached from the productive San Andres shelf and shelf margin carbonates present along the Northwest Shelf, the Central Basin Platform, and the western end of the Pennsylvanian Horseshoe Atoll (Figure 1). During San Andres (Permian, lower Guadalupian) time, the Tedbit structure was one of a number shoals or intermittent islands in a generally basinal, inter-platform setting.

The San Andres Formation consists of multiple shallowing-upward, carbonate-evaporite cycles, each cycle representing subtidal open marine to arid supratidal depositional environments. San Andres cycles in Tedbit Field are truncated, lacking the anhydritic caps typical of cycles deposited on the surrounding shelves. Dolomitized oolitic grainstones, originally deposited in shallow subtidal, high-energy, mobile carbonate sand tracts, provide the reservoir facies in Tedbit Field. Several thin (4'-20') grainstone intervals, with micro-vuggy and intercrystalline porosity, are productive in the field. These reservoirs are best developed on the south flank of the Tedbit structure, pinch out updip, and are absent over the crest of the structure. Seals are provided by overlying and interbedded low-permeability dolomitic and slightly anhydritic mudstones.

Tedbit (San Andres) Field

Tedbit Field was discovered in 1971 in the plugged-back Weiner Shelton No. 1 well, and developed with a total of 17 wells drilled between 1971 and 1991. The 11 completed wells have produced a total of 432,303 barrels of oil and 28.179 million cubic feet of gas through December 1999. No gas is currently being marketed. Initial potential rates ranged from 13 BOPD to 92 BOPD of 31° API gravity oil. Initial water saturations averaged 31.5 percent. Net pay within the field ranges from 20 feet to 56 feet, with a field average of 30 feet. Average reservoir porosity is 7 percent, although thin intervals reach 11 percent. No permeability data are available. However, low production rates and the extended time span of production suggests that permeability is relatively low. The reservoir drive mechanism appears to be mainly gas expansion, although a weak edge water drive may also be present. Water production has been low to moderate, and no oil-water contact has been defined. No pressure maintenance programs or secondary recovery operations have been initiated.

Oil & Gas Properties Wood No. 1 well

The Oil & Gas Properties Wood No. 1 well, drilled by Advance Oil Company in 1975 to a depth of 11,000 feet, was plugged-back and completed through casing in the Tedbit (San Andres) Field. Two pay zones (5004'-5016'and 5026'-5032') are present. These zones were initially opened with 10 perforations (Figure 2) and acidized with 6500 gallons of 15 percent hydrochloric acid. The well potentialled pumping, 56 barrels of oil and 5 barrels of water per day (GOR: 214), in February 1976. Produced oil is 31° API, sour, and paraffinic. Since completion, the well has remained on production (Figure 3), with no additional reservoir stimulation.

Remedial work was limited to rod repair and hot oil treatments to minimize paraffin buildup.

The Wood No. 1 well was selected to be the test site for water-jet horizontal drilling technology as it is typical of a large number of Permian Basin San Andres stripper wells. Specifically, the well produces through casing, has thin reservoir zones, has produced for over 20 years, and has received no reservoir stimulation since initial completion. Geologic factors, including low permeability, significant depletion, low reservoir pressure, and the probability of compartmentalized reservoir, were also considered to be fairly typical.

PROJECT SUMMARY

The following chronology describes well site operations throughout the field test of water-jet horizontal drilling technology. This information is included to provide a record of actual procedures and events.

05/05/00 Rigged up pulling unit and shut down over night. Left well pumping.

05/08/00 Pulled rods, pump, and production tubing out of well. Ran casing scraper and bit to 5063 feet. Pulled out of hole with scraper. Picked up packers, setting nipple, and valve on production tubing string. Ran in hole and set packer at 4967 feet. Loaded back side with 27 barrels of water. Pumped 500 gallons of *Petrosol X-25*™ solvent, flushed with 15 barrels of 2% KCl water. Shut down over night.

05/09/00 Attempted to swab inside of production tubing string. Swab stuck at 800 feet. Pulled and cut line, retrieved swab. Released packer. Ran paraffin knife on rod to 2085 feet'. Pulled out of hole with paraffin knife, found little paraffin on knife. Pulled out of hole with packer and laid down production tubing. Rigged up logger, ran gamma ray and casing collar locator logs. Pulled out of hole with logging tools. Picked up elbow sub-assembly on production tubing and ran in hole. Set elbow at 5013 feet. Ran in hole with log for correlation and found production tubing set at 5012 feet. Pulled tubing up 15 inches to position elbow and reset for lateral. Shot fluid level at 3812 feet. Shut down over night.

05/10/00 Ran in hole with coiled tubing and jet nozzle to 4265 feet (fluid level). Worked coiled tubing but could not get below 4285 feet. Came out of hole with coiled tubing. Jet nozzle and lower 4 to 6 feet of composite tubing was heavily coated with soft black sludge. Rigged up for hot oil and hot oiled production tubing with 20 barrels of lease crude oil and 25 barrels of 2% KCl water. Ran in hole with coiled tubing and jet nozzle, could not get below fluid level at 2835 feet. Pulled out of hole with coiled tubing. Ran in hole 1000' with paraffin knife, had two tight spots. Pulled out of hole with paraffin knife, changed washers. Ran in hole to 3200 feet with paraffin knife, pulled out of hole. Ran in hole with paraffin knife, could not get below 2800 feet. Pulled out of hole with paraffin knife. Pulled production tubing string out of hole and checked elbow for debris. Found little debris in elbow. Cleaned and ran rabbit through all production tubing. Found 6 joints of tubing with tight spots. Replaced bad tubing joints. Ran in hole with elbow and production string. Reset elbow at 5013 feet. Shut down over night.

05/11/00 Heated water-jet drilling water. Ran in hole with coiled tubing and jet nozzle, jetting with hot water while running in. Blew out hot water connection to coiled tubing. Shut down 30 minutes to repair connection. Continued to bottom and attempted to jet without progress. Pulled out of hole with coiled tubing. Picked up milling assembly. Ran in hole with coiled tubing to mill casing. Mill assembly hung up at 2252 feet. Worked coiled tubing for 25 minutes and got milling assembly to bottom. Milled on casing for 1 hour and 20 minutes. Pulled out of hole with milling assembly. Checked mill bit and changed drill water filter. Noted that small amount of paint was missing from tip of mill bit and bit collar. Ran in hole with coiled tubing and jet nozzle to attempt to cut lateral. Jetted for 1 hour with possible 3 feet of progress (5048 feet to 5051 feet). Pulled out of hole with coiled tubing and rigged down water-jet equipment. Pulled out of hole with production tubing and elbow. Shut down over night.

05/12/00 Picked up packer and ran in hole with production tubing. Set tubing at 4930 feet. Rigged up to pump 1000 gallons of acid with 20 balls. Ran acid job with maximum pressure of 800 p.s.i., had ball action but did not ball out.

Initial shut in pressure:	225 p.s.i.
5" shut in pressure:	140 p.s.i.
10" shut in pressure:	100 p.s.i.
15" shut in pressure:	70 p.s.i.

Shut down over night.

Following the acid treatment the well was returned to production.

CONCLUSIONS

The testing of the Advanced Petroleum Enhancement, Inc. water-jet horizontal drilling technology was conducted with inconclusive results. Unexpected mechanical problems and an abundance of paraffinic sludge were encountered in the wellbore. Either of these factors may have contributed to initially preventing the water-jet tool from reaching the kick-off point. Once the milling assembly was in position at the kick-off point and milling operations were conducted, the successful cutting of a casing window could not be demonstrated. Examination of the milling assembly, specifically the lack of significant paint abrasion on the mill bit, suggests that a full diameter casing window may not have been cut. Whether additional milling was warranted is unknown. The subsequent attempt to jet a lateral drain hole was clearly unsuccessful, although as much as 3 feet may have been cut. As the reasons for the lack project success cannot be determined with the available information, no conclusions are drawn here with regard to the viability or application of this technology.

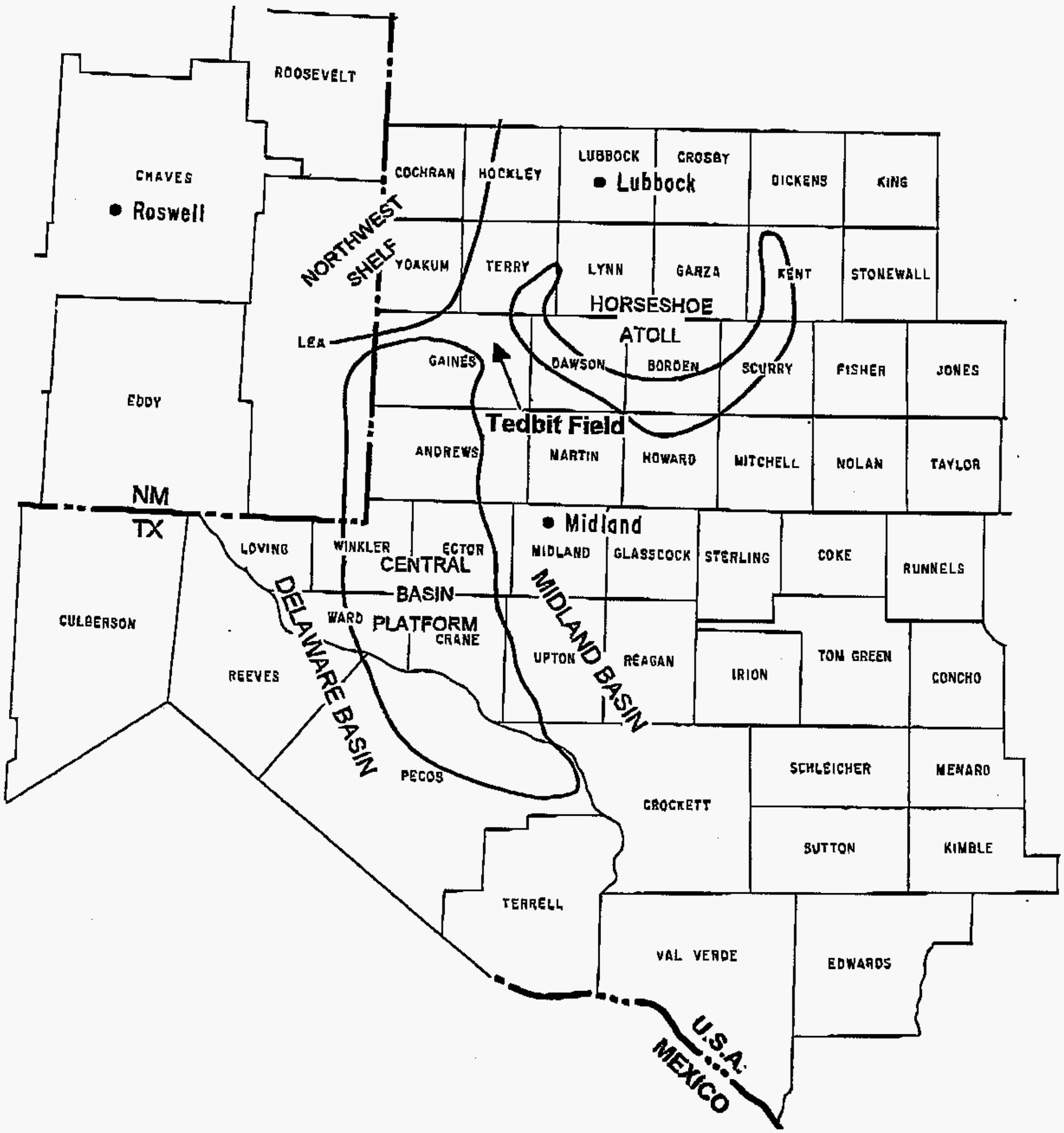


Figure 1. Location Map.

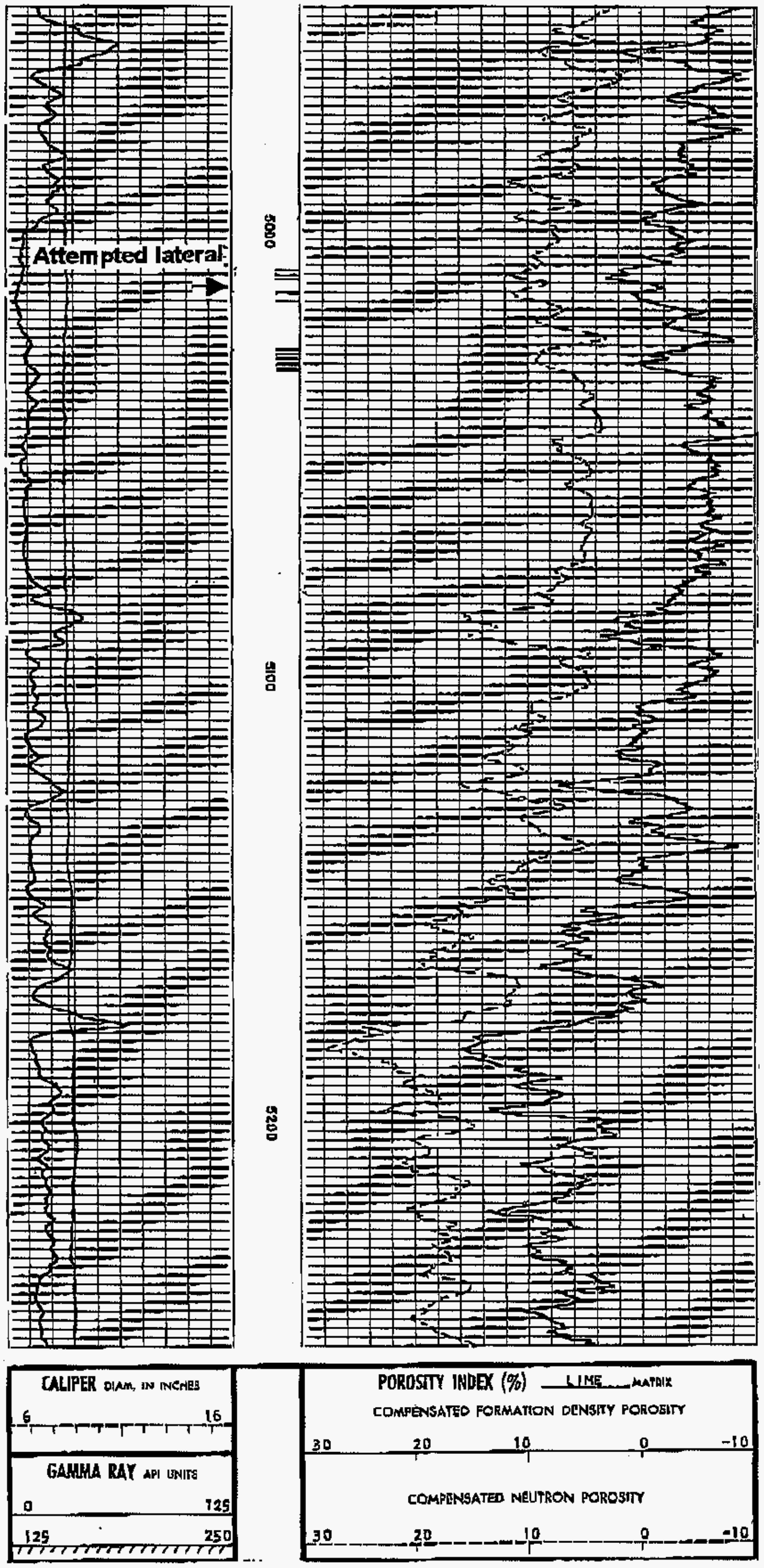
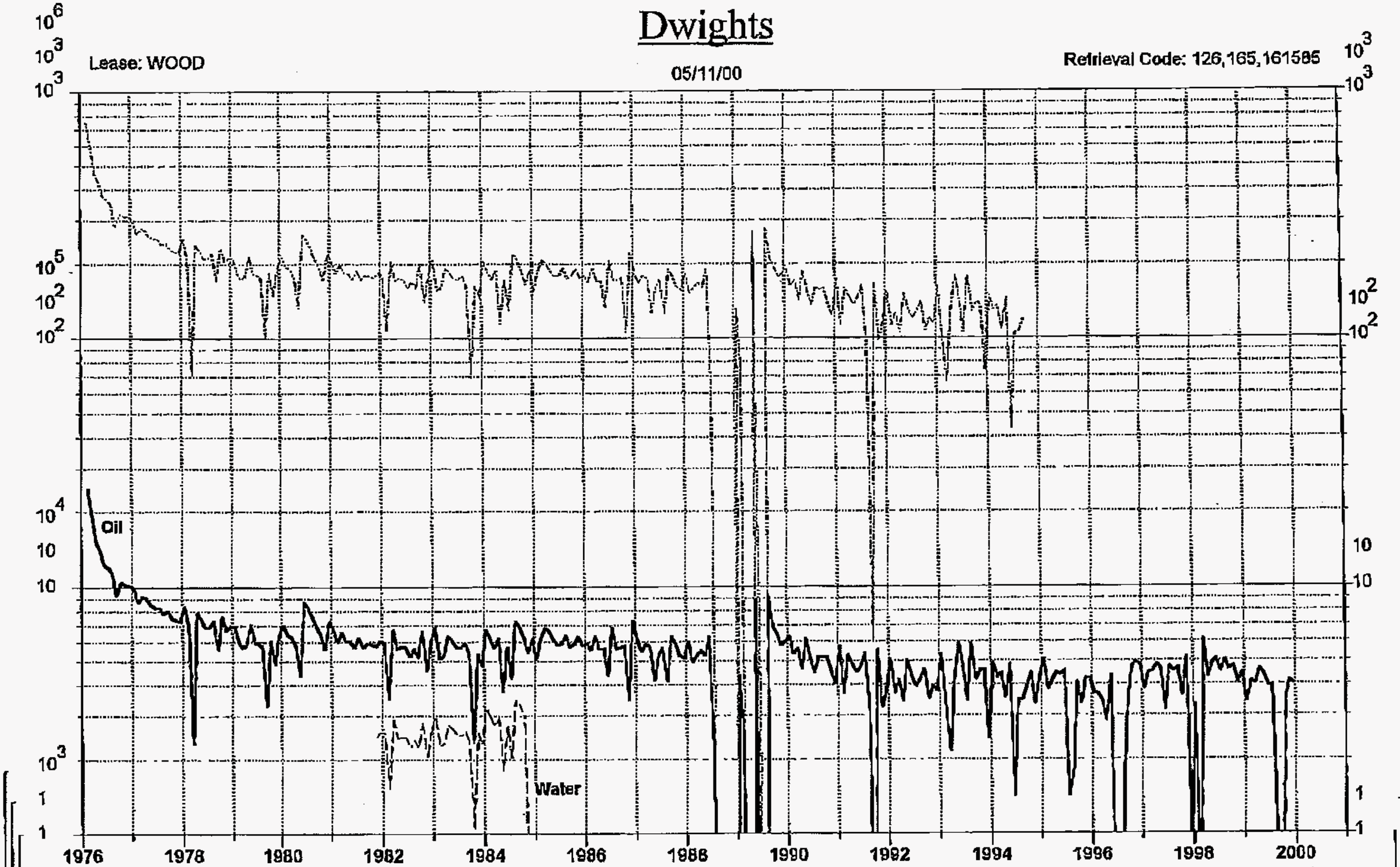


Figure 2. Neutron-Density Log.
Oil & Gas Properties Wood No. 1.



Oil (bbl/day)

Gas (mcf/day)

Yield (bbl/mmcf)

County: GAINES, TX	F.P. Date: 02/76
Field: TEDBIT (SAN ANDRES)	Oil Cum: 46.52 mbbl
Reservoir: SAN ANDRES	Gas Cum: 216 mcf
Operator: OIL & GAS PROPERTIES INC	API #: 42-165-3051200

Water (bbl/day)

Well Count

**Figure 3. Production Curve.
Oil & Gas Properties Wood No. 1.**